THE AMERICAN MINERALOGIST

VOL. I NOVEMBER, 1916 No. 5

A REVIEW OF THE GENESIS OF THE ZEOLITE DEPOSITS OF FIRST WATCHUNG MOUNTAIN, N, J.[1]

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INTRODUCTION

NEW JERSEY is fortunate in having many famous mineral localities, and of these perhaps the most frequently visited by collectors are the trap quarries of First Watchung Mountain, especially those at West Paterson and Great Notch.

These occurrences have also received considerable attention from investigators, but the conclusions which have been arrived at as to the genesis of the minerals are not in general familiar to collectors. This is particularly true concerning some of the more recent discoveries, and the present paper has been written to call attention to these discoveries and the resulting conclusions as to the genesis of these remarkable mineral deposits.

GEOLOGY[2]

The rocks of this region are of Triassic age and consist of sedimentary rocks with interbedded basalt flows, the whole collectively known as the Newark Group.

The sedimentaries comprise fine-grained red shale, sandstone, conglomerate, and dark colored argillite or mudstone; the source of the materials having evidently been the gneiss, quartzite and limestone of the Highland belt to the west. Ripple-marks, mud-cracks, rain-drop impressions, foot-prints of reptiles, and mineral cavities are frequently found. These sedimentaries are now believed to be of continental origin, deposited under semi-arid conditions in basins at the foot of the then newly uplifted Appalachian Mountains.

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[1] Read before the Philadelphia Mineralogical Society, September 14, 1916.

[2] See U. S. Geol. Survey, Passaic Folio, **157**, 1911.

> Numerous short but vigorous streams brought down the debris of the disintegrating and decomposing granites, gneisses and metamorphic sediments of earlier Paleozoic age, and deposited them in coalescing alluvial fans across the smoother plain of the crystalline Piedmont. Occasional downward movements of warping or faulting gave opportunity for local thickening of the deposits. . . .[3]

Similar deposits are now forming in the Great Basin of the western United States where extensive sediments are being laid down on the floors of sinking basins at the foot of the Sierras. In these saline residues, mud-cracks of great depth and ripple-marks are much in evidence. It is only under such conditions that thoro oxidation of the iron in sediments can occur; this, it is believed, accounts for the prevalent red color of the beds of the Newark Group.

In many of the beds glauberite[4] and halite[5] cavities are found, these minerals having formed in Triassic "playas" or temporary lakes, as they became concentrated thru evaporation.

During the deposition of these continental sediments, igneous activity interposed toward the close of the Triassic period. Three basalt flows mark this epoch in the vicinity of Paterson. Due to greater resistance to weathering as compared with the softer sedimentaries, the basalt masses rise above the surrounding country as prominent ridges, known as First, Second and Third Watchung Mountains. The mineral localities of importance are found in the first, those of West Paterson at a part of the mountain known as Garrett Rock.

The local features shown by the basalts are thus explained by Fenner.[6]

> The flow spread over the surface of the accumulating sediments and filled the depressions occupied by the playa lakes. Over the dry areas, the lava came to rest quietly, and the normal process of cooling and crystallization followed without interruption. The rock formed under these conditions presents a dense, homogeneous mass, which, under the microscope, is found to have the holocrystalline texture normal to basalts. Over the lake beds, however, the lava . . . was quickly chilled from

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[3] J. Volney Lewis, The origin and relations of the Newark rocks, Ann. Rept. State Geologist of New Jersey, **1906**, p. 107.

[4] E. T. Wherry, Glauberite crystal-cavities in Triassic rocks. *Am. Min.* **1**, (3), 37–43.

[5] B. K. Emerson, Bull. U. S. Geol. Survey **126**, 144, 1895.

[6] C. N. Fenner, Features indicative of physiographic conditions prevailing at the time of the trap extrusions in New Jersey, *J. Geol.* **16**, 299, 1908. The Watchung basalt and the paragenesis of its zeolites and other secondary minerals, *Ann. N. Y. Acad. Sci.*, **20**, 93, 1910.

the effects of water and vaporized steam. An exposure in the southwestern part of Paterson shows a mixture of lava and very fine mud several feet in thickness, and in many other places the lava was rendered extremely vesicular. The upper portions were not so thoroly impregnated with steam but were, nevertheless, quickly cooled and became viscous. The jets and tongues of fused material seem to have assumed the consistency of a thick syrup and instead of spreading laterally they solidified in smoothly rounded boulder-like masses, having considerable similarity to the 'pahoehoe' of Hawaiian flows. . . . The rounded forms are sometimes built up to a thickness of 60–70 feet. The interior of the boulders cooled with sufficient slowness to permit the basalt to crystallize with normal texture, but each is sheathed with a crust of glass (tachylite) varying from an inch to several inches in thickness, having often a laminated structure. Where unaltered the color is usually dark olive-green or brown, and the appearance is decidedly vitreous. . . .

The crusts frequently present a shattered appearance due to the sudden chill which they have experienced, and at times pockets among the boulders are filled with considerable masses of breccia of this nature.[7]

The Zeolite Deposits

Occurrence: The secondary minerals form nests and pockets in the angular spaces between adjacent boulder-forms and wrap around them in bands in the situation in which the glassy crusts were originally developed.[8]

This is due to the fact that the glass passed more easily into solution than the basalt, and formed the channels of easiest circulation.

. . . Alteration also followed the shrinkage cracks which penetrate the interior of the normally crystallized interior of the boulders and produced veinlike bands of secondary minerals in a breccia of unaltered basalt.[9]

A study of the field relations has shown that the spheroidal masses of basalt, sheathed with glassy crusts, appear in areas which, at the time of the basalt flow, were covered by shallow lakes, and that these areas coincide with those in which the formation of zeolitic minerals has occurred.[10]

Source of the waters which deposited the zeolites: The query arises as to the origin of the circulating waters, whether meteoric or magmatic. . . . In the case of these zeolitic deposits . . . several lines of evidence lead to the conclusion that the waters were of extraneous origin. Field observation shows that the secondary alteration extends to within a few feet of the lower surface of the trap sheet, and points to an uprise of waters from the underlying shales.[11]

The aqueous contents of the lava would be completely expelled into the open air. The source of the waters which effected alteration must, therefore, be sought elsewhere. A theory of derivation from meteoric sources by a process of underground circulation appears to fill the requirements of the situation and to offer no obstacle. The preëxistent topographic depressions in the areas occupied by the lakes, altho buried by the flow of lava, would nevertheless be reached by waters flowing in from the edge of the sheet thru the porous sedimentary strata lying just beneath the impervious mass of normally crystallized igneous rock. Having reached such depressions, the hydrostatic head would be that due to the difference in elevation between the depressions and the point of ingress. The somewhat loose and porous structure of the accumulations of lava above the preëxistent lakes being favorable for percolation, the waters would naturally tend to rise to the surface. A circumstance favorable to this result lay in the fact that the lava retained a store of heat long after consolidation. Immediately after the latter event the temperature was so high that apparently all water which gained access was vaporized, notwithstanding the impediments to escape caused by restrictions of the channel; but as the temperature fell, the water level in this arm of the system of circulation slowly rose.

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[7] Fenner, second paper cited, pp. 100 and 101.

[8] Fenner, *ibid.* p. 109.

[9] Fenner, *ibid.* p. 111.

[10] Fenner, *ibid.* p. 102.

[11] Fenner, *ibid.* p. 104.

The system of circulation thus conceived is analogous to that of artesian flows, only modified in this respect, that the effective head was not so much due to a difference in elevation between the points of ingress and exit, as to vaporization of the water in the upper portions of the channel of exit.[12]

. . . Among the spheroidal masses, a considerable amount of interstitial space had been left. Moreover, the crusts were much shattered, and frequently the interiors of the masses were penetrated by a multitude of cracks produced by shrinkage in cooling. Where the openings were of sufficient size to permit free passage of superheated vapors from the water-impregnated sediments beneath, these gases seem to have rushed upward with great force and velocity, carrying with them quantities of finely comminuted dust from the lake beds and depositing it in the various interstices, in the form of a reddish-brown powder. . . . Mingled with this material, there are fragments of basaltic glass, whose nature is easily recognized.[13]

The general process was that of the slow but constant and uninterrupted cooling of igneous rock thru which aqueous solutions were percolating, deriving their heat from the enclosing rock and cooling as it cooled. . . . With progressive fall of temperature conditions of equilibrium within the solutions were shifted, and new species were deposited. In these later changes, the material which participated was derived both from the first deposited minerals, which had now become unstable, and from new supplies of igneous rock, to which access was now gained.

The constant removal of material in solution undoubtedly enlarged the channels of circulations and, in places, produced cavities of considerable size. The most perfect crystals are naturally found in vugs of this kind. It does not appear, however, that such openings were at all necessary for recrystallization, and in most cases they were not present. The leaching appears to have been somewhat selective, for iron and magnesia are greatly reduced in the later stages.[14]

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[12] Fenner, *ibid.* p. 106. [13] Fenner, *ibid.* p. 103. [14] Fenner, *ibid.* p. 112.

> It was found difficult at first to account in a satisfactory manner for the introduction of such quantities of carbonic acid as the abundance of calcite requires. . . . The hypothesis which was finally adopted as being most probable was that the meteoric waters of the general form of circulation, . . . retained some store of the originally dissolved carbonic acid (probably as bicarbonate of lime, $CaH_2(CO_3)_2$, and carbonates of the alkalies) at the period of their history at which they entered the basalt sheet on the return journey to the surface. When conditions became favorable, this supply of dissolved carbonic acid reacted with the various original and secondary lime silicates at moderate temperatures. When the temperature is high, on the contrary, the process is reversed, so that carbonate rocks carrying silica, passing from the zone of katamorphism into the zone of anamorphism, where high temperatures prevail, have the carbonic acid driven off, while the lime combines with the silica, and produces lime silicates. The process is, therefore, easily a reversible one under variations of temperature. This probably accounts for the observed fact that little or no calcite appears to have been formed in the Watchung series during the prevalence of the more elevated temperatures under which the minerals of the first and second periods were deposited, and it was not until very moderate temperatures were reached that carbonation became the chief feature, tending to destroy the previously formed silicates.[15]

The theory of the source of the circulating waters above outlined is open to some question. It seems evident that the formation of the zeolites has locally been determined to a great extent by the development of basalt glass easily susceptible to alteration, which in turn was determined by the situation of the preëxisting lakes. Contact metamorphism of the shale beneath the basalt would render it quite impervious and an effective seal against invasion of waters from that direction. Even were such a circulation possible, it would undoubtedly have passed completely under the basalt to the opposite edge of the sheet, rather than thru the hot rocks above, as this would have formed the easiest path.

The present writer believes that the more plausible explanation is that the water involved was furnished both by the playa lakes and the magma itself. That considerable water was absorbed from these lakes by the basalt in its incursion cannot be doubted, and is evidenced by the development of anhydrite and glauberite, which distinguish these deposits from those of most other famous zeolite localities. Then, too, the solutions inherent in the magma cannot be disregarded.

At Moore Station, N. J., zeolites are found in contraction fissures in diabase, and are believed to owe their origin to magmatic water exuded during the last stages of cooling into the contraction fissures. In the case of the Watchung basalt the zeolites may have been derived by alteration of the basalt glass and to a lesser extent of the normal basalt by solutions due to mingling of absorbed lake water and emanations from the cooling boulders.

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[15] Fenner, *ibid.* p. 175.

The objection may be raised that the aqueous contents of the lava would have been completely expelled into the open air immediately upon its extrusion. Zeolites are, however, not uncommon in basalts, and amygdaloidal deposits are present in many occurrences of these rocks, and the origin in both cases may safely be ascribed to solutions from the original magma. It is quite possible that covering by later flows is a potent factor in the development of such zeolite deposits, for the cooling of the magma and formation of secondary minerals must under such circumstances continue long after other flows have sealed the top.

The mud found admixed with the zeolites and the glass would naturally be supposed to be the result of stirring up of the lake bottom by the basalt as it rolled along; much mud would be kept in suspension by circulating waters until the zeolites had been deposited,—often entering them as inclusions.

> The majority of the secondary minerals are found to consist of the elements present in the original plagioclase feldspar, with or without addition of water. The possibilities of equilibrium among the great number of compounds present was considered in the light of Gibbs's phase rule, and some inquiry was made into the applicability of this rule to the conditions of the problem. It was deemed most probable that, altho various modifying conditions entered whose effect could not be wholly taken into account, the general conclusions to which the phase rule pointed should hold and that the possibility of all the compounds present coexisting in equilibrium could not be admitted.[16]
>
> The processes of alteration may be divided . . . into . . . periods, which with their characteristic minerals are as follows:[17]
>
> Period I. Boric acid period.
> Stage 1. Albite, quartz, garnet, amphiboles, specularite, sulfides.
> Stage 2. Datolite, prehnite, pectolite, amphiboles, specularite, sulfides.
>
> Period II. Zeolite period.
> Analcite, chabazite, heulandite, stilbite, natrolite, scolecite, laumontite, apophyllite, amphiboles, chlorite, specularite, sulfides.
>
> Period III. Calcite period.
> Thaumasite, calcite, gypsum, amphiboles, chlorite, specularite, sulfides.

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[16] Fenner, *ibid.* p. 186; see also pp. 115–121.

[17] Fenner, *ibid.* p. 120.

Dr. Fenner has made an exhaustive study of the sequences of the minerals at West Paterson and Great Notch, examining many specimens and thin sections. The paper is replete with descriptions of slides and specimens, and extended discussions of the relationships of the minerals.

Attention may be called, however, to albite which is found replacing labradorite. Dr. Fenner believes that the various molecules entering into the feldspars are chemically independent, and presents the theory that

> . . . the anorthite molecule was continually leached out of the labradorite, while albite was deposited in its place, a chief feature being probably a growth of crystals at the expense of others in the vicinity.[18]

Some of the most interesting specimens to be found at the quarries are the well known "pseudomorphous cavities" found in quartz, prehnite, datolite, and pectolite. These have long been known under the misnomer "quartz pseudo pectolite" or in a few instances, quartz pseudo some zeolite. Two types of crystals are represented by the cavities, one rectangular in outline, thick to thin tabular in habit, and evidently orthorhombic; the other lozenge or "diamond"-shaped in cross section, prismatic in habit, and monoclinic in symmetry.[19]

Babingtonite was described from Paterson by Dr. Fenner[20] in 1914 and he suggested that this was the original mineral of the cavities. But Mr. F. I. Allen[21] discovered anhydrite in McKiernan and Bergin's quarry about the same time, in all stages of alteration to gypsum or thaumasite; and study has shown that this mineral was undoubtedly the one to which most of the rectangular cavities are due.

More recently loose casts of quartz in the lozenge-shaped cavities have been found, showing well defined prismatic and pyramidal faces, and these were shown by Dr. Wherry[22] to be due to glauberite.

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[18] Fenner, *ibid.* p. 122.

[19] E. T. Wherry, The lozenge-shaped cavities in the First Watchung Mountain zeolite deposits, *J. Wash. Acad. Sci.*, **6**, (7), 182, 1916.

[20] C. N. Fenner. Babingtonite from Passaic County, N. J., *J. Wash. Acad. Sci.*, **4**, 553-558, 1914. Additional notes on babingtonite from Passaic Co., N. J., *ibid.*, 598–605.

[21] F. I. Allen, N. Y. Times, Nov. 23, 1914; *Am. J. Sci.*, **39**, 134, 1915.

[22] E. T. Wherry, *loc. cit.*

An interesting specimen of gypsum is shown in Plate V. The back of the crystal shows a pseudomorph of gypsum after anhydrite. The anhydrite was evidently the first mineral to form, and received a coating of quartz crystals; later, the anhydrite was replaced by gypsum, which recrystallized and became the nucleus of a much larger crystal, which has since suffered corrosion of the faces as shown in the first figure.

TABLE I. PRINCIPAL MINERALS OF THE DEPOSITS

Mineral	*Composition*					*Genetic relation*	
Labradorite	1	Na Al		Si_3O_8		Primary	
	1–3	Ca Al		Si_2O_8		"	
Babingtonite		$(Ca, Fe, Mn) Fe_2$		$(SiO_3)_4$		"	
Augite	m	Ca Mg		$(SiO_3)_2$		"	
	n	$(Mg, Fe) (Al, Fe)_2$		SiO_6		"	
Olivine		$(Mg, Fe)_2$		SiO_4		"	
Albite		Na Al		Si_3O_8		Hydrothermal	metamorph
Amphibole		(Ca, Mg, Fe)		SiO_3		"	"
		Na Al		$(SiO_3)_2$		"	"
Garnet		$(Mg, Fe)_3 Al_2$		$(SiO_4)_3$		"	"
Chlorite	H_8	$(Mg, Fe)_5 Al_2$		$(SiO_6)_3$		"	"
Specularite		Fe_2		O_3		"	"
Pyrite?		Fe		S_2		"	"
Chalcopyrite		Fe Cu		S_2		"	"
Sphalerite		Zn		S		"	"
Galena		Pb		S		"	"
Quartz				SiO_2		"	"
Chalcedony				SiO_2		"	"
Calcite		Ca		CO_3		"	"
Anhydrite		Ca		SO_4		"	"
(Glauberite)		$Ca Na_2$		$(SO_4)_2$		"	"
Analcite		Na	Al	Si_2O_6.	H_2O	"	"
Chabazite		(Na_2, Ca)	Al_2	$(SiO_3)_4$.	$6H_2O$	"	"
Gmelinite		(Na_2, Ca)	Al_2	$(SiO_3)_4$.	$6H_2O$	"	"
Pectolite	H	Na	Ca_2	$(SiO_3)_3$		"	"
Datolite			Ca B (OH)	SiO_4		"	"
Apophyllite		(H, K_2) Ca		$(SiO_3)_2$.	H_2O	"	"
Prehnite	H_2		$Ca_2 Al_2$	$(SiO_4)_3$		"	"
Natrolite		Na_2	Al_2	Si_3O_{10}.	$2H_2O$	"	"
Scolecite		Ca	Al_2	Si_3O_{10}.	$2H_2O$	"	"
Mesolite	m	Na_2	Al_2	Si_3O_{10}.	$2H_2O$	"	"
	n	Ca	Al_2	Si_3O_{10}.	$2H_2O$	"	"
Thomsonite		Ca	Al_2	Si_2O_8.	$2\frac{1}{2}H_2O$	"	"
Laumontite		Ca	Al_2	$(SiO_3)_4$.	$4H_2O$	"	"
Stilbite		Ca	Al_2	Si_6O_{16}.	$6H_2O$	"	"
Heulandite		Ca	Al_2	Si_6O_{16}.	$5H_2O$	"	"
Opal				SiO_2.	nH_2O	Weathering	product
Gypsum		Ca		SO_4.	$2H_2O$	"	"
Thaumasite		Ca_3	$(OH)_3(CO_2)$	$(SO_3)(HSiO_4)$.	$12H_2O$	"	"
Aragonite		Ca		CO_3		"	"
Malachite		Cu_2	$(OH)_2$	CO_3		"	"
Azurite		Cu_3	$(OH)_2$	$(CO_3)_2$		"	"
Limonite		Fe_4	$O_3(OH)_6$			"	"
Stevensite	H_2	Mg_3		$(SiO_3)_4$.	H_2O	"	"

Burgerite and rutgersite, alteration products of apophyllite of indefinite composition.

THE COMPOSITION OF THAUMASITE FROM GREAT NOTCH, NEW JERSEY

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THE mineral thaumasite, calcium carbono-silico-sulfate crystallizing with 15 molecules of water in the hexagonal system, has long been known to occur at West Paterson, New Jersey, analyses having been published by Penfield and Pratt in 1896.[1] Its presence at other mineral localities in the First Watchung Mountain basalt would naturally be expected. About 1908 a block 2 x 1 x 1 feet in size, and probably weighing originally over 100 pounds, was discovered in the Francisco Quarry at Great Notch. For some time this stood in front of the office, and the superintendent of the quarry permitted Mr. James G. Manchester, president of the New York Mineralogical Club, to break a few small specimens from it. The mass was subsequently broken up and distributed to various museums. Mr. Manchester kindly furnished the writer, thru Dr. Edgar T. Wherry, of the United States National Museum, a sample for analysis. The specimen from which this was broken has since been added to the collection of the National Museum (Catalog No. 92,955).

The material is minutely crystalline and snow white, and under the microscope appears quite homogeneous. Its indices of refraction[2] are $\omega = 1.505$ and $\epsilon = 1.468$, essentially identical with the values observed on other specimens. Analyses were performed by standard methods, two each by Mr. G. C. Foresman and Mr. J. C. Yon, of the writer's class in quantitative analysis, and one by the writer personally. The results are given in the following table:

TABLE I. ANALYSES OF THAUMASITE FROM GREAT NOTCH, N. J.

	1	2	3	4	5	6
CaO	27.0	26.78	26.88	26.07	26.65	27.18
MgO	....	tr.	tr.	tr.	tr.	0.02
$(Al, Fe)_2O_3$	....	0.72	0.64	0.75	0.65	0.20
CO_2	7.1	9.11	9.25	8.15	7.89	7.97
SiO_2	9.6	8.68	8.85	9.14	9.14	9.36
SO_3	12.9	12.62	12.74	13.91	13.72	13.03
H_2O (Below 100°)	....	....	....	....	....	0.32
H_2O (Above 100°)	43.4	41.98	41.98	41.98	41.98	42.24
	100.0	99.89	100.34	99.80	100.13	100.31

1. Theory for $CaCO_3.CaSiO_3.CaSO_4.15H_2O$.
4 and 5. Analyses by Mr. Foresman.
2 and 3. Analyses by Mr. Yon.
6. Analysis by the writer.

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[1] Am. J. Sci., [4], **1**, 229, 1896.

[2] As determined by Dr. Wherry.

THE PHILADELPHIA MINERALOGICAL SOCIETY

The Wagner Free Institute of Science, September 14, 1916.

A stated meeting of the Philadelphia Mineralogical Society was held on the above date with President Trudell in the chair. Those present were Allen, Bradford, Egee, Flack, Geist, Gordon, Groth, Jones, Knabe, Leffman, Rothermel, Streland, and Trudell.

Mr. Rothermel gave a brief account of a trip to the Grand Canyon and the Petrified Forest, exhibiting many specimens. Mr. Gordon reported a trip to West Paterson, and one to South Mountain, Adams and Franklin Co., Pa.; and read a paper on "A Review of the genesis of the zeolite deposits of First Watchung Mountain, N. J." illustrated with numerous specimens.

The following officers were nominated for 1916–1917: President, Mr. Harry W. Trudell; Vice President, Mr. E. A. Groth; Secretary, Mr. Samuel G. Gordon; Treasurer, Mr. Oscar Streland.

Samuel G. Gordon, *Secretary*.

REVIEWS AND ABSTRACTS

LIST OF WORKS RELATING TO THE GEOLOGY, MINERALOGY AND PALEONTOLOGY OF NEW JERSEY.

George Fraser Black. *Bulletin of the N. Y. Public Library*. June 1916. Reprint Sept. 1916. 36 pp.

A very interesting and comprehensive index to papers on the minerals of New Jersey in the Library. In most cases gives a brief abstract of, or mentions the minerals discussed in each paper. Certain omissions may be noted: the discovery of willemite from Franklin, N. J. announced as silicate of zinc in the listed paper by Vanuxem and Keating, J. Acad. Nat. Sci. Phila. **4**, 8, 1824. Also the announcement of the fluorescence of willemite from Franklin, N. J. in the unlisted paper, Annals N. Y. Acad. Sci. **11**, No. 17, 402–403, Oct. 13, 1898.

Some later reprints of certain listed papers might have been included and perhaps also certain papers which discuss correlations of L. I. and N. J. geologic features as listed in U. S. Geol. Survey Prof. Paper No. 82, The geology of Long Island, N. Y., by M. L. Fuller.

It will interest members of the N. Y. Min. Club to note how many of its former and present members have contributed to the list of works here compiled. Some of them are Apgar, F. W. (under the name of Apgood, an error of the journal cited); Canfield, F. A.; Gratacap, L. P.; Hawkins, A. C ; Hollick, A.; Hunt, J. H.; Hovey, E. O.; Johnson, D. W.; Julien, A. A.; Kemp, J. F.; Kunz, Geo. F.; Levison, W. G.; Martin, D. S.; Rogers, A. F.; and Whitfield, R. P. W. G. L.

HANDBOOK AND DESCRIPTIVE CATALOGUE OF THE METEORITE COLLECTIONS IN THE UNITED STATES NATIONAL MUSEUM.[1] George P. Merrill. *U. S. Nat. Mus. Bull.* **94**, 207 pp., 41 pl., 1916.

"The handbook and catalog presented herewith is intended primarily for the use of the general public, but the subject matter is at the same time so arranged as to meet the needs of the student and investigator as well . . . ."

The classification, mineral and chemical composition, structure, early records and opinions, phenomena and number of falls, of meteorites are briefly discussed in Part I. Part II is a catalog of the U. S. National Museum collections which number 412 falls (this has since been increased to 432 falls), including that of the recently acquired C. U. Shepard collection of 234 falls, 83 of which are not represented in the National Museum collection proper (of 329 falls and an equal number of thin sections). The meteorites are fully described with numerous analyses and excellent plates of specimens and thin sections, reference being facilitated by the alfabetical arrangement. Moldavites, billitonites, and other glasses of supposed meteoric origin, are discussed, and instances of terrestrial irons are cited, in the two appendices.

S. G. G.

ANNUAL REPORT OF THE INTERNATIONAL COMMITTEE ON ATOMIC WEIGHTS, 1917. F. W. Clarke, T. E. Thorpe, and G. Urbain. *J. Chem. Soc.*, **109** and **110**, 777, 1916.

The committee suggests that Cb should be altered to 93.1, otherwise the table for 1916 remains unchanged. S. G. G.

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[1] Copies of this catalog can be obtained from the Superintendent of Documents, Washington, D. C., for 55 cents.

THE ORIGIN OF TOPAZ AND CASSITERITE AT GUNANG BAKAU, MALAYA. William R. Jones. *Geol. Mag.* [6], **3,** (6), 255–260, 1916.

"The topaz-bearing rocks of Gunang Bakau bear striking similarities in their mode of occurrence and mineral content to those found in other tin-fields, and especially those of Erzgebirge." Evidence is brought forward to show that the topaz and cassiterite are of secondary origin, produced by "greisenization" (hydrothermal metamorphism) of the granite by fluorine-bearing vapors. S. G. G.

SERICITE, A LOW TEMPERATURE HYDROTHERMAL MINERAL. Austin F. Rogers, of Leland Stanford Junior University. *Econ. Geol.* **11,** (2), 118–150, 1916.

Sericite, tho very similar to, if not identical with, muscovite in chemical composition, may be considered a distinct mineral and not simply a variety of muscovite. The greatest development of sericite is in altered wall-rocks of ore-bearing veins and in metamorphic rocks, not only replacing silicates, but also the various sulfides. It is a low temperature mineral formed at, or towards the close of the hydrothermal period, or in a corresponding late stage in metamorphic rocks. Sericite apparently does not form in the zone of weathering and probably not in the zone of static metamorphism. S. G. G.

NEW MINERAL NAMES. W. E. Ford, of Yale University. *Am. J. Sci.* [4], **41,** (6), 566–570, 1916.

It is planned to publish lists of new mineral names in the last numbers of volumes of the Am. J. Sci., to serve, in a measure, as a continuous supplement to Dana's System of Mineralogy. The first is here presented, the minerals being arranged alfabetically, followed by a supplementary list in which the new names are arranged according to the chemical classification. The original reference and the principal physical and chemical properties are mentioned under each name. S. G. G.

THE SEVERAL FORMS OF CALCIUM CARBONATE.

JOHN JOHNSTON, H. E. MERWIN, and E. D. WILLIAMSON, of the Geophysical Laboratory. *Am. J. Sci.*, [4], **41,** (6), 473–512, 1916.

At ordinary temperatures calcium carbonate exists in at least three anhydrous crystalline forms,—the two well known forms calcite and aragonite, and another designated by the writers μ-$CaCO_3$. Four other reputed forms, the so-called vaterite, conchite, ktypeite, and lublinite have also been described; there seems now to be little doubt that vaterite is a porous calcite, that conchite and ktypeite are porous aragonite, and that lublinite is merely a special variety of calcite. A number of hydrates have also been described, but with the exception of one, the hexahydrate, $CaCO_3.6H_2O$, their definite existence is uncertain, since the experimental evidence leaves much to be desired.

The writers discuss the various physical and chemical methods for the identification of the various forms. It is their opinion that the chemical methods should not be used alone as they are indecisive, particularly so where they are most useful. This opinion is based in part upon a number of observations outlined, and in part upon the fact that some of the factors upon which the tests depend are very difficult to control.

Calcite is, at ordinary pressure, the stable form of calcium carbonate at all temperatures from 0° (or lower) up to 970° at which temperature it inverts to α-$CaCO_3$; under these conditions aragonite and $\mu CaCO_3$ are always unstable with respect to calcite, tho there is an indication that aragonite has a stable field of existence at about $-100°$ or lower. Under all ordinary conditions, therefore, pure aragonite tends to go over into calcite; how far it does so depends upon the rate of transformation under the particular circumstances. There is, therefore, no definite transition point; and the interval required is comparatively long. By reason of this instability, one cannot specify the factor or factors which determine the precipitation of $CaCO_3$ as aragonite; indeed, its appearance would seem to be a matter of chance.

In so far as the writers have been able to ascertain, natural aragonite is formed (a) thru organic agencies, (b) by deposition from hot springs, (c) when an isomorphous carbonate is present to serve as a nucleus, (d) in salt waters containing sulfate even at ordinary temperatures. Pure aragonite can persist as such only when dry; but aragonite containing other substances in solid solution may thereby be enabled to persist in the presence of certain solutions. There are indications that the μ-form (hexagonal) often occurs as an intermediate step in the precipitation of the other forms, but it soon transforms in the presence of water. The properties of these three forms and of the hexahydrate are described, and their solubility discussed. S. G. G.

SOME MINERALS FROM THE FLUORITE-BARITE VEIN NEAR WAGON WHEEL GAP, COLORADO.

Esper S. Larsen and Roger C. Wells, of the U. S. Geological Survey. *Proc. Nat. Acad. Sci.*, **2,** (7), 360–365, 1916.

Description of gearksutite and *creedite*—a new fluoride-sulfate (see below under NEW SPECIES), occurring at Wagon Wheel Gap, Colorado.

GEARKSUTITE

Color: snow-white. Form: powdery balls, becoming plastic when wet, and without grit. Under the microscope homogeneous, composed of an aggregate of threads. Sp. Gr. 2.768. $n = 1.454 \pm 0.003$, with moderate birefringence.

An analysis by Wells gave: Al_2O_3 28.49, Fe_2O_3 tr., CaO 31.37, MgO tr., Na_2O .05, K_2O .08, F 41.00, $-H_2O$ .44, H_2O 15.20; less O for F 17.27, total 99.36, agreeing with $CaF_2.Al(F,OH)_3.H_2O$; F:OH = 2:1.

The gearksutite is believed to have been formed by metasomatic alteration of the rhyolitic wall rock by the hot ascending solutions which deposited the fluorite in the vein [hydrothermal metamorphism of rhyolite]. S. G. G.

NEW SPECIES

Creedite

Esper S. Larsen and Roger C. Wells, of the U. S. Geological Survey: SOME MINERALS FROM THE FLUORITE-BARITE VEIN NEAR WAGON WHEEL GAP, COLORADO. *Proc. Nat. Acad. Sci.*, **2,** (7), 360–365, 1916.

Name: From the Creede quadrangle, Colorado, where it occurs.

PHYSICAL PROPERTIES

Color: white to colorless. Form: grains and crystals. H. = about 3.5 Sp. gr. = 2.730.

CRYSTALLOGRAPHIC PROPERTIES

Monoclinic, with the faces (110), perfect cleavage (100), tw. pl. (100). $110 \wedge 110 = 59° - 60°$ Habit: stout prismatic, with an acute rhombic section. Faces are usually dull, curved, and imperfect; one crystal showed curved and striated pyramidal faces.

OPTICAL PROPERTIES

Optically $-$. $\alpha = 1.461$, $\beta = 1.478$, $\gamma = 1.485$.

$Y = b$; $Z \wedge c = 41°$. 2V computed 65°, measured:

$2V_{Li} = 64°30' \pm 10'$; $2V_{Na} = 64°22' \pm 10'$; $2V_{Tl} = 64°20' \pm 10'$.

Cleavage fragments show ‖ extinction.

CHEMICAL PROPERTIES

Comp. $CaSO_4.2CaF_2.2Al(F,OH)_3.2H_2O$; F:OH = 2:1; requiring Al 11.0, Ca 24.4, SO_4 19.5, O 3.2, H_2O 11.0, F 30.9 = 100.0. Analyses by Wells gave: Al 11.58, Ca 23.98, SO_4 18.32, O 3.97, $-H_2O$ 0.72, H_2O 11.08, F 30.35; O and F calculated on basis of summation of 100%. Creedite intumesces B.B. and finally fuses to a white enamel. Slowly but completely soluble in acid.

The creedite is imbedded in an isotropic kaolinite-like mineral with rather unusual properties. Sp. gr. 2.548, n 1.557±0.003. A partial analysis gave Wells SiO_2 44.2, Al_2O_3 40.2, CaO 0.3, MgO tr., Ign. 15.5, total 100.2 S. G. G.

Margarosanite

W. E. Ford and W. M. Bradley: MARGAROSANITE, A NEW LEAD-CALCIUM SILICATE FROM FRANKLIN, N. J. *Am. J. Sci.*, [4], **42**, (2), 159–162, 1916.

Name: From the Greek *margarites*, pearl and *sanis*, tablet, referring to its luster and structure.

PHYSICAL PROPERTIES

Colorless. Transparent. Luster, pearly. Form: lamellar masses of thin plates closely packed together, showing a rhombic outline due to cleavages. H 2.5–3. Sp.gr. 3.991.

CRYSTALLOGRAPHIC PROPERTIES

Probably triclinic. Principal cleavage || to tabular development, with two others, apparently but not exactly, perpendicular to the first. Traces of these latter cleavage directions make approximate angles of 102° and 78° with each other on the surfaces of the plates.

OPTICAL PROPERTIES

The two extinction directions in the sections make angles of about 44° and 46° with one of the cleavage directions, and of 34° and 56° with the other. $n = 1.730 \pm .002$ and $1.795 \pm .005$; the latter must be close to β.

CHEMICAL PROPERTIES

Comp. $PbCa_2(SiO_3)_3$, SiO_2 35.10, PbO 43.17, CaO 21.73 = 100. CaO replaced by a little MnO. Analysis by Bradley, recalculated after eliminating the water (hydroscopic) and substituting CaO for a little MnO: SiO_2 33.77, PbO 43.57, CaO 22.66 = 100. Pyr. Fuses with some difficulty in O.F. assuming an amethyst color; but in R.F. fuses easily and quietly at about 2 to an opaque grayish glass. In R.F. gives a pale azure-blue flame with a pale green border. With fluxes on charcoal it gives a metallic globule of lead accompanied by a lead oxide coating. It gives the characteristic Mn color tests, and is decomposed by HNO_3 yielding separated silica.

Observed on specimens of almandite, hancockite, roeblingite, nasonite, franklinite, willemite, axinite, datolite, manganophyllite, and barite from about the 1000 foot level of the Parker Shaft, at Franklin, N. J. S. G. G.

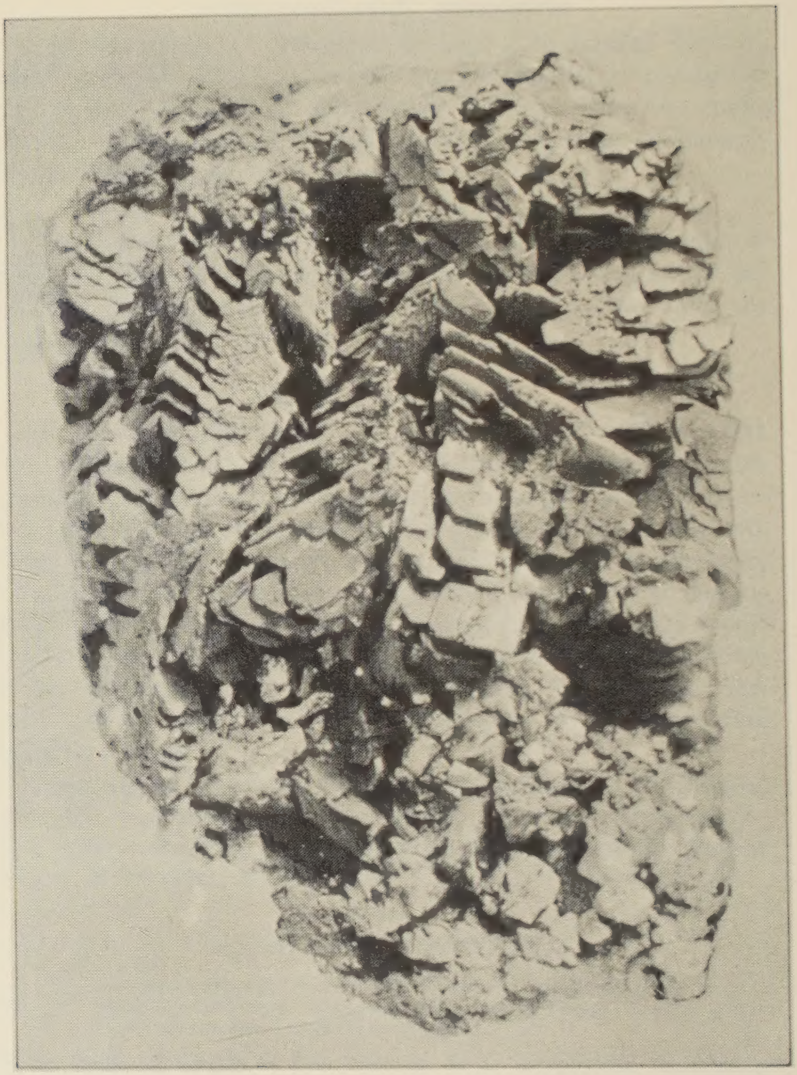
EXCHANGES OFFERED

Exchange notices will be printed free of charge to our subscribers in this column for three months or three times a year, as desired. Goods for sale must be offered in the advertising columns.

B. C. Beegle, 52 Chadwick Ave., Newark, N. J. Apophyllite, thaumasite, prehnite, stilbite, red quartz, heulandite, calcite.

John Holzman, 182 Ridgewood Ave., Newark, N. J. Heulandite, prehnite, pectolite, red and smoky quartz, fine twin crystals of calcite. Write for list.

J. P. Wintringham, 153 Henry St., Brooklyn, N. Y. Wanted: triclinic, monoclinic, or orthorhombic crystals for crystallographic measurement or for sections; pericline twins—single or polysynthetic or plagioclases of known composition. Please state what is wanted in return.



Photograph by Samuel G. Gordon

CHALCOPYRITE, FALLS OF FRENCH CREEK, CHESTER CO., PA.

PLATE VI